

Claims

1. A nitrogen-free ozone generator system, comprising:

a first electrode;

a second electrode which is opposite to the first electrode and forms a discharge region having a gap;

raw material gas supply means for supplying an oxygen gas as a raw material gas; and

a catalytic material which is provided on a dielectric or the electrode in the discharge region and contains a photocatalytic material with a band gap of 2.0 eV to 2.9 eV, wherein

an AC voltage is applied between the first electrode and the second electrode from a power supply to inject discharge electric power into the discharge region, the oxygen gas is supplied from the raw material gas supply means to the discharge region,

discharge light having at least a light wavelength in a range of 428 nm to 620 nm is irradiated to the catalytic material by discharge, the catalytic material is excited to dissociate the oxygen gas passing through the discharge region into oxygen atoms, a gas pressure of the discharge region through which the oxygen gas passes is kept at 0.1 MPa to 0.4 MPa, and the oxygen gas and the dissociated oxygen atom are subjected to a bonding process to generate an ozone gas.

2. A nitrogen-free ozone generator system according to claim 1, wherein purity of the oxygen gas is 99.99% or higher.
3. A nitrogen-free ozone generator system according to claim 1, wherein a gap interval of the discharge region having the gap is 0.6 mm or less.
4. A nitrogen-free ozone generator system according to claim 1, wherein a noble gas as an auxiliary gas is contained in the oxygen gas at 500 ppm to 50000 ppm with respect to the oxygen gas, and an ozone generation reaction is accelerated.
5. A nitrogen-free ozone generator system according to claim 1, wherein the catalytic material is applied to a wall surface of the dielectric or the electrode in the discharge region, and a contact surface area between the catalytic material and the discharge light is 1.5 times as large as an area of the dielectric or the electrode.
6. A nitrogen-free ozone generator system according to claim 1, wherein the catalytic material is a powder of the photocatalytic material having a particle diameter of 0.1 μm to 50 μm and adhered to a wall surface of the dielectric or the electrode in the discharge region to increase a surface area.
7. A nitrogen-free ozone generator system according to claim 1, wherein a roughness of 1 μm to 50 μm is formed on a wall surface of the dielectric or the electrode in the discharge region, the catalytic material is provided on the wall surface

on which the roughness is formed, and a surface area of the catalytic material is increased.

8. A nitrogen-free ozone generator system according to claim 1, wherein the dielectric in the discharge region is a dielectric through which the discharge light passes, and the catalytic material is the photocatalytic material powder of 1% to 10% in volume ratio contained in the dielectric through which the discharge light passes.

9. A nitrogen-free ozone generator system according to claim 1, wherein the photocatalytic material is provided on the electrode in the discharge region, and the photocatalytic material on a discharge region side is covered with the dielectric through which the discharge light passes.

10. A nitrogen-free ozone generator system according to claim 1, wherein the photocatalytic material includes at least one of Cu_2O , In_2O_3 , Fe_2TiO_3 , Fe_2O_3 , Cr_2O_3 , PbO , V_2O_5 , FeTiO_3 , WO_3 and Bi_2O_3 .

11. A nitrogen-free ozone generator system according to claim 1, wherein the photocatalytic material includes at least one of materials made of rare-earth metal ion complexes of $\text{Nb}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{W}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{Ta}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{In}_{2m}\text{P}_4\text{O}_{4m+4}$, BaTi_4O_9 , $\text{MnTi}_6\text{O}_{13}$, $\text{TiO}_a\text{Nb}_b\text{F}_c$, $\text{SrTiO}_a\text{Nb}_b\text{F}_c$, $\text{BaTiO}_a\text{Nb}_b\text{F}_c$ and plural elements.

12. A nitrogen-free ozone generator system according to claim 1, wherein the photocatalytic material is doped with a material as an auxiliary catalyst of Ru, Ni, Pt, RuO_2 , NiOx

or NiO.

13. A nitrogen-free ozone generator system according to claim 4, wherein the catalytic material is applied to a wall surface of the dielectric or the electrode in the discharge region, and a contact surface area between the catalytic material and the discharge light is 1.5 times as large as an area of the dielectric or the electrode.

14. A nitrogen-free ozone generator system according to claim 4, wherein the catalytic material is a powder of the photocatalytic material having a particle diameter of 0.1 μm to 50 μm and adhered to a wall surface of the dielectric or the electrode in the discharge region to increase a surface area.

15. A nitrogen-free ozone generator system according to claim 4, wherein a roughness of 1 μm to 50 μm is formed on a wall surface of the dielectric or the electrode in the discharge region, the catalytic material is provided on the wall surface on which the roughness is formed, and a surface area of the catalytic material is increased.

16. A nitrogen-free ozone generator system according to claim 4, wherein the dielectric in the discharge region is a dielectric through which the discharge light passes, and the catalytic material is a photocatalytic material powder of 1% to 10% in volume ratio contained in the dielectric through which the discharge light passes.

17. A nitrogen-free ozone generator system according to claim 4, wherein the photocatalytic material is provided on the electrode in the discharge region, and the photocatalytic material on a discharge region side is covered with the dielectric through which the discharge light passes.

18. A nitrogen-free ozone generator system according to claim 4, wherein the photocatalytic material includes at least one of Cu_2O , In_2O_3 , Fe_2TiO_3 , Fe_2O_3 , Cr_2O_3 , PbO , V_2O_5 , FeTiO_3 , WO_3 and Bi_2O_3 .

19. A nitrogen-free ozone generator system according to claim 4, wherein the photocatalytic material includes at least one of materials made of rare-earth metal ion complexes of $\text{Nb}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{W}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{Ta}_{2m}\text{P}_4\text{O}_{6m+4}$, $\text{In}_{2m}\text{P}_4\text{O}_{4m+4}$, BaTi_4O_9 , $\text{MnTi}_6\text{O}_{13}$, $\text{TiO}_a\text{Nb}_b\text{F}_c$, $\text{SrTiO}_a\text{Nb}_b\text{F}_c$, $\text{BaTiO}_a\text{Nb}_b\text{F}_c$ and plural elements.

20. A nitrogen-free ozone generator system according to claim 4, wherein the photocatalytic material is doped with a material as an auxiliary catalyst of Ru, Ni, Pt, RuO_2 , NiOX or NiO .

21. A nitrogen suppression ozone generator system, comprising:

a first electrode;

a second electrode which is opposite to the first electrode and forms a discharge region having a gap;

raw material gas supply means for supplying an oxygen gas as a raw material gas;

nitrogen gas supply means for supplying a nitrogen gas;
and

a catalytic material which is provided on a dielectric or the electrode in the discharge region and contains a photocatalytic material with a band gap of 2.0 eV to 3.6 eV, wherein

an AC voltage is applied between the first electrode and the second electrode from a power supply to inject discharge electric power into the discharge region,

the oxygen gas is supplied from the raw material gas supply means to the discharge region, the nitrogen gas in a range of 10 ppm to 500 ppm is supplied for acceleration of an ozone generation reaction to the oxygen gas from the nitrogen gas supply means,

discharge light having at least a light wavelength in a range of 344 nm to 620 nm is irradiated to the catalytic material by discharge, the catalytic material is excited to dissociate the oxygen gas passing through the discharge region into oxygen atoms, a gas pressure of the discharge region through which the oxygen gas passes is kept at 0.1 MPa to 0.4 MPa, and the oxygen gas and the dissociated oxygen atom are subjected to a bonding process to generate an ozone gas.

22. A nitrogen suppression ozone generator system according to claim 21, wherein a noble gas as an auxiliary gas is contained in the oxygen gas at 500 ppm to 50000 ppm with

respect to the oxygen gas, and an ozone generation reaction is accelerated.

23. A nitrogen suppression ozone generator system according to claim 21, wherein the catalytic material is applied to a wall surface of the dielectric or the electrode in the discharge region, and a contact surface area between the catalytic material and the discharge light is 1.5 times as large as an area of the dielectric or the electrode.

24. A nitrogen suppression ozone generator system according to claim 21, wherein the catalytic material is a powder of the photocatalytic material having a particle diameter of 0.1 μm to 50 μm and adhered to a wall surface of the dielectric or the electrode in the discharge region to increase a surface area.

25. A nitrogen suppression ozone generator system according to claim 21, wherein a roughness of 1 μm to 50 μm is formed on a wall surface of the dielectric or the electrode in the discharge region, the catalytic material is provided on the wall surface on which the roughness is formed, and a surface area of the catalytic material is increased.

26. A nitrogen suppression ozone generator system according to claim 21, wherein the dielectric in the discharge region is a dielectric through which the discharge light passes, and the catalytic material is a photocatalytic material powder of 1% to 10% in volume ratio contained in the dielectric through

which the discharge light passes.

27. A nitrogen-free ozone generator system according to any one of claims 1 to 20, used for a chemical vapor deposition apparatus or an ALD (atomic layer deposition) thin film deposition apparatus.

28. A nitrogen-free ozone generator system according to any one of claims 1 to 20, used for a chemical vapor deposition apparatus or an ALD (atomic layer deposition) thin film deposition apparatus for producing any one of a nonvolatile memory ferroelectric thin film, a high dielectric constant dielectric thin film, a nitride metal thin film, an oxide metal, an optical material thin film, a high density photomagnetic recording thin film, a superconducting thin film, and a high quality capacitor thin film.

29. A nitrogen-free ozone generator system according to any one of claims 1 to 20, used for an ozone condensing apparatus.

30. A nitrogen-free ozone generator system according to any one of claims 1 to 20, used for a pulp bleaching apparatus.

31. A nitrogen-free ozone generating method provided with a first electrode, a second electrode which is opposite to the first electrode and forms a discharge region having a gap,

raw material gas supply means for supplying an oxygen gas as a raw material gas, and

a catalytic material which is provided on a dielectric or the electrode in the discharge region and contains a

photocatalytic material with a band gap of 2.0 eV to 2.9 eV, wherein

an AC voltage is applied between the first electrode and the second electrode from a power supply to inject discharge electric power into the discharge region, the oxygen gas is supplied from the raw material gas supply means to the discharge region,

discharge light having at least a light wavelength in a range of 428 nm to 620 nm is irradiated to the catalytic material by discharge, the catalytic material is excited to dissociate the oxygen gas passing through the discharge region into oxygen atoms, a gas pressure of the discharge region through which the oxygen gas passes is kept at 0.1 MPa to 0.4 MPa, and the oxygen gas and the dissociated oxygen atom are subjected to a bonding process to generate an ozone gas.

32. A nitrogen suppression ozone generating method, provided with a first electrode, a second electrode which is opposite to the first electrode and forms a discharge region having a gap, raw material gas supply means for supplying an oxygen gas as a raw material gas,

nitrogen gas supply means for supplying a nitrogen gas, and

a catalytic material which is provided on a dielectric or the electrode in the discharge region and contains a photocatalytic material with a band gap of 2.0 eV to 3.6 eV,